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Introductory Comments on Philosophy and Constructivism in Science Education

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ABSTRACT: This article indicates something of the enormous influence of constructivism on contemporary science education. The article distinguishes educational constructivism (that has its origins in theories of children's learning), from constructivism in the philosophy of science (usually associated with instrumentalist views of scientific theory), and from constructivism in the sociology of science (of which the Edinburgh Strong Programme in the sociology of scientific knowledge is the best known example). It notes the expansion of educational constructivism from initial considerations of how children come to learn, to views about epistemology, educational theory, ethics, and the cognitive claims of science. From the learning-theory beginnings of constructivism, and at each stage of its growth, philosophical questions arise that deserve the attention of educators. Among other things, the article identifies some theoretical problems concerning constructivist teaching of the content of science.

Constructivism is a major influence in contemporary science and mathematics education. And in its post-modernist or 'deconstructivist' version, it is a significant influence in literary, artistic, historical, social science and even theological education. Constructivism, in all its varieties, has been the subject of heated debate. The debate is not simply about the adequacy of a particular learning theory, or the cogency of an epistemological position, or the fruitfulness of a hermeneutical principle. Something more is at stake. This is suggested by the frequency with which constructivists link their position to ideas of empowerment and emancipation – ideas that clearly outrun mere learning theory or epistemology. Many commentators have remarked on how frequently constructivists stake out the moral high ground for their position (see especially Kilpatrick 1987). But their occupancy is not without dispute. Paul Gross and Norman Levitt's book *Higher Superstition* (Gross & Levitt 1994) has given wide popular exposure to the anti-constructivist cause. Michael Devitt has written that:

> I have a candidate for *the* most dangerous contemporary intellectual tendency, it is . . . constructivism. Constructivism is a combination of two Kantian ideas with twentieth-century relativism. The two Kantian ideas are, first, that we make the known world by imposing concepts, and, second, that the independent world is (at most) a mere 'thing-in-itself' forever beyond our ken. . . . [considering] its role in France, in the social sciences, in literature departments, and in some largely well-meaning, but confused, political movements [it] has led to a veritable epidemic of 'worldmaking'. Constructivism attacks the immune system that saves us from silliness. (Devitt 1991, p. ix).

Debate not withstanding, constructivism is influential in Western education. A former president of the US National Association for Research in Science Teaching (NARST) has said that 'A unification of thinking, research, curriculum development, and teacher education appears to now

be occurring under the theme of constructivism . . . there is a lack of polarised debate' (Yeany 1991, p. 1 – for references see Bibliography at end of issue). The American Association for the Advancement of Science has published a nineteen-chapter book titled *The Practice of Constructivism in Science Education*, the Preface of which states that 'there is widespread acceptance of constructivism', and that 'constructivism has become increasingly popular . . . in the past 10 years', indeed it represents a 'paradigm change' in science education (Tobin 1993 – see Book Notes section of this issue). A 1990 bibliography produced at Leeds University, a major centre of constructivist research, listed over 1,000 works (Carmichael et al. 1990). Reinders Duit, at the Institute for Science Education in Kiel, has been performing the Herculean task of keeping up-to-date with research in this field, and his estimate is that there are currently 2,500 constructivist-inspired scholarly research articles in education journals (Duit 1993). The constructivist research programmes at Monash University, Waikato University, Florida State University, and Leeds University – to name perhaps the major centres – have been energetic and productive.

Although there have been some critics of constructivism (Suchting 1992, Matthews 1993, Phillips 1995, Osborne 1996), and some urging caution in its adoption (Millar 1989, Solomon 1993), few would dispute Peter Fensham's claim that 'The most conspicuous psychological influence on curriculum thinking in science since 1980 has been the constructivist view of learning' (Fensham 1992, p. 801).

THE TRANSFORMATION OF CONSTRUCTIVISM

It is important to notice that Fensham speaks of 'psychological influence', and the constructivist 'view of learning'. This is the original core of constructivism – a psychological theory about how beliefs are developed, not what makes beliefs true or what counts as scientific knowledge. From this core, constructivism has expanded to incorporate views about epistemology, teaching, curriculum, educational theory, ethics, ontology, and metaphysics.

But even at its learning-theory core epistemology is involved. Jean Piaget well recognised that any decent learning theory involves epistemological considerations – he called his own research programme 'Genetic Epistemology', and one of his most influential books is titled *Psychology and Epistemology: Towards a Theory of Knowledge* (Piaget 1972). More recently Kenneth Strike and George Posner have said that their oft-cited 1982 paper – 'Accommodation of a Scientific Conception: Toward a Theory of Conceptual Change' (Posner et al. 1982) – is 'largely an epistemological theory, not a psychological theory . . . it is rooted in a conception of the kinds of things that count as *good* reasons' (Strike & Posner 1992, p. 150). Thus from the core outwards, constructivism neces-

sarily involves considerations of philosophy – something for which, unfortunately, science teachers are often ill-prepared by their training.

There are of course many varieties of constructivism (see for instance Good et al. (1993), Phillips (1995) and Geelan (this issue)). For the sake of convenience these may be divided into educational constructivism, philosophical constructivism, and sociological constructivism. The first variety itself divides into personal and social constructivism. The second variety has its immediate origins in Thomas Kuhn's work, and is most robustly represented by Bas van Fraasen, a recent President of the US Philosophy of Science Association. This philosophical constructivism has its roots in Berkeleys philosophy of science, and further back in instrumentalist philosophy of Ancient Greece. This tradition has been, since Aristotle, opposed by realists in the philosophy of science (see Matthews 1994, chap. 8). Sociological constructivism is identified with the Edinburgh 'Strong Programme' and their research on the Sociology of Scientific Knowledge (SSK). In this tradition the growth of science, and changes in its theories and philosophical commitments, is interpreted in terms of changing social conditions and interests; and the explanatory power of cognitive content and rational reasoning is discounted. That is, that something is true and reasonable is not thought, by adherents to the Edinburgh Programme, to constitute an explanation of why it is believed.

PHILOSOPHY AND EDUCATIONAL CONSTRUCTIVISM

Educational constructivism draws upon the other constructivist – philosophical and sociological – traditions, but it has its own autonomous roots and history. Educational constructivism of the personal variety stresses the individual creation of knowledge and construction of concepts. This stream has its origins in Piaget's Kantian-inspired theories of cognitive development, and Ernst von Glasersfeld is perhaps its best known representative (see Hardy & Taylor, this issue). Educational constructivism of the social variety stresses the importance of the group (be it the immediate classroom or the wider culture) for the development and validation of ideas. This has its origins in Vygotsky's work in linguistics and language acquisition, and is seen, for instance, in the later publications of Rosalind Driver.

A working distinction can be drawn between constructivist theory and constructivist pedagogy. The need for this distinction was brought home to me some years ago at an international science education conference when I was raising epistemological questions with one leading constructivist, who replied: "Michael, what I am interested in is good teaching, all the other stuff [epistemology, cognitive psychology] is peripheral". There is of course, a variety of constructivist postions on this theory/practice matter. Many think constructivist epistemology and cognitive psychology is germane to the pedagogical prescriptions; others like the

conference presentator think that the theory is much less important than the practice; others concentrate solely on pedagogy, and improved classroom practices, and simply use the label 'constructivist' to refer to anything which is pupil-centered, engaging, questioning, and progressive. For the latter, the details of epistemology and cognitive psychology are unimportant, and not worth disputing about. They might be called, if labels are required, 'pedagogical constructivists'.

The collection of papers in this double-issue of *Science & Education* are all focussed on philosophical, particularly epistemological, aspects of educational constructivism, or those parts of the other constructivist traditions that have been utilised in the educational literature. Guides to the debate, and literature, about constructivism in the philosophy of science can be found in Leplin (1984), Churchland & Hooker (1985), and Brown (1994). Comparable guides to constructivism in the sociology of scientific knowledge can be found in Brown (1984) and McMullin (1988, 1992).

The guiding idea behind this journal issue is that the epistemological claims of educational constructivism are important, and that they deserve further delineation and investigation.

The New Zealand Example

Unfortunately matters of deep philosophical importance over which there have been centuries of debate, too frequently appear almost as throw-away lines in science education writing. 'When they are elaborated, the elaboration is often slight, being little more than the citing of names, or claims that 'since Kuhn such and such', or 'following Kant so and so', or 'Latour has shown that something or other'. There have of course been deeper analyses, many of which are discussed by contributors, and cited in this issue's bibliography. But overall the theoretical, pedagogical and curriculum proposals of educational constructivism are like an inverted pyramid: they rest on a tiny base. It is in everyone's interest that this base be made more substantial, and be well scrutinised.

For example, the very influential and much-reprinted book of Roger Osborne and Peter Freyberg – *Learning in Science: The Implications of Children's Science* (Osborne & Freyberg, 1985) opens with the statement that:

> Young children and scientists have much in common. Both are interested in a wide variety of objects and events in the world around them. Both are interested in, and attempt to make sense of, how and why things behave as they do. (Osborne & Freyberg 1985, p. 1)

This idea – that science is about making sense of the world, rather than finding out about the world – has been much debated in the history of philosophy. But the book does not elaborate the debate or defend its position.

The book concludes with a statement of the *sine qua none* of constructivism – the non-transferability of knowledge thesis:

> Knowledge is acquired not by the internalisation of some outside given but is constructed from within. (Osborne & Freyberg 1985, p. 82)

Again there is no elaboration or defense of this, to put it mildly, contentious position. The alternative position in learning theory is one that maintains:

> if you want somebody to know something, you teach it to them . . . if you want somebody to know something and retain it for a long period of time, then you have them practice it. (Geary 1995, p. 33)

These casual, almost throw-away epistemological positions have cast a long shadow in New Zealand education. For instance, the New Zealand National Curriculum in Science (1993) labels the chief learning areas: 'Making Sense of the Living World' (instead of Biology, or Finding Out About the Living World), and 'Making Sense of Planet Earth and Beyond' (instead of Astronomy, or Finding Out About the Solar System). And a 1990 draft syllabus identifies the 'Role of the Teacher' as being: 'Helping students learn how to learn; being a learner too; ensuring equity for all students; creating a friendly, supportive learning environment; providing learning opportunities; listening to students; using the students' ideas, experiences, and interests; challenging sensitively the ideas of students; providing resources to help students learn; ensuring students communicate in a variety of modes; identifying and nurturing the scientific talent and interests of all students – provided that teachers are aware of the effectiveness of an open science programme which allows students to realise their own potential at their own pace; and finally, contributing to the planning of the school science programme'. This list has everything except knowing the subject matter to be taught, and being able to teach it in a clear, engaging and understandable manner.

There is a not-too-subtle difference between the constructivist formulation 'making sense', and the realist formulation 'finding out'. The former has no epistemological or referential bite; the latter has both. Things can make perfect sense without being true; and making still more sense does not imply any increase in truth content.

At this stage the point of the New Zealand example (elaborated in Matthews 1995) is only to illustrate the claim that frequently in science education far-reaching philosophical claims are made without the intellectual support that their importance warrants. Many rush into philosophical positions, where fearing to tread is a wiser policy.

ETHICS, POLITICS AND IDEOLOGY IN CONSTRUCTIVIST THOUGHT

Thus far, constructivist theory has been spoken about in its *epistemological* guise, and three varieties – educational, philosophy of science, and sociological – have been mentioned. But epistemology is not the only area into which constructivist theory has expanded.

Constructivism also has an *ethical* dimension. A recent paper says 'There is also a sense in which constructivism implies caring – caring for ideas, personal theories, self image, human development, professional esteem, people – it is not a take-it-or-leave-it epistemology' (Watts 1994, p. 52). This ethical dimension is manifest in the frequency with which notions of emancipation and empowerment occur in constructivist writing. Constructivism is thought to be a morally superior position to its rivals in learning theory and pedagogy (see Hardy & Taylor, this issue).

There is also a *political* dimension to much constructivist writing. Two constructivist writers say that they are 'committed to the philosophy and principles of composite grades and mixed-ability groupings' (Brass & Duke 1994, p. 100). Another writer has identified the Progressive Education tradition as constructivist, and the British Plowden Report of the mid-1960s as the embodiment of constructivist school organisation (Hawkins 1994).

A number of constructivists align themselves with the Critical Theory of Michael Apple, Henry Giroux and Stanley Aronowitz. One New Zealand commentator says that 'There are many parallels between the literature on the development of critical pedagogy [and] the literature on constructivist learning' (Gilbert 1993, p. 35). This is because 'Critical theorists question the value of such concepts as individualism, efficiency, rationality and objectivity, and the forms of curriculum and pedagogy that have developed from these concepts' (Gilbert 1993, p. 20).

One commentator sees constructivism as a component of cultural ideology, saying that:

> In sum, constructivism is largely a reflection of current American cultural beliefs and, as such, involves the development of instructional techniques that attempt to make the acquisition of complex mathematical skills an enjoyable social enterprise that will be pursued on the basis of individual interest and choice. (Geary 1995, p. 32)

For some, constructivism has gone beyond learning and educational theory, into the realms of metaphysics and worldviews. Ken Tobin, a past president of the US National Association for Research in Science Teaching, has said:

> To become a constructivist is to use constructivism as a referent for thoughts and actions. That is to say when thinking or acting, beliefs associated with constructivism assume a higher value than other beliefs. For a variety of reasons the process is not easy. (Tobin 1991, p. 1)

What needs to be recognised is that many things are being said in the name of constructivism that transend its original domain of learning

theory. It is frequently assumed that constructivist learning theory has these flow-on effects into epistemology, educational theory, political theory, ideology, and metaphysics. For many, constructivism presents itself as a package deal: if you buy the learning theory, then you buy the epistemology and everything else. Conversely, if you are in favour of educational reform, and the emancipation and liberation of human beings, then you must be a constructivist in learning theory and pedagogy.

Clearly we need to disentangle, and to examine carefully, these different elements. The contributors to this special issue largely focus on the epistemological aspects of constructivist theory. But this is not to say that the ethical, political and educational – in the sense of educational theory – aspects of constructivism are unimportant. They certainly are important, and also need to be thoroughly examined. It is now basically accepted that when science educators speak of epistemological matters they need to be, to some extent, familiar with the tradition of epistemological debate in philosophy. So educators who speak of ethics, emancipation, empowerment and social justice should also be familiar with the long tradition of philosophical debate about ethics, politics, educational theory, and social theory. Without this familiarity (something that courses in philosophy can provide), the risk is that educators merely repeat popular nostrums, or voice politically correct fashions.

Constructivism has done a service to science education by alerting teachers to the function of prior learning and extant concepts in the process of learning new material, by stressing the importance of understanding as a goal of science instruction, by fostering pupil engagement in lessons, and other such progressive matters. But liberal educationalists can rightly say that these are pedagogical commonplaces, the recognition of which goes back at least to Socrates. It is clear that the best of constructivist pedagogy can be had without constructivist epistemology – Socrates, Montaigne, Locke, Mill, and Russell are just some who have conjoined engaging, constructivist-like pedagogy with non-constructivist epistemology.

Constructivism has also done a service by making educators aware of the human dimension of science: its fallibility, its connection to culture and interests, the place of convention in scientific theory, the historicity of concepts, the contested nature of theories, and much else. But again realist philosophers can rightly maintain that constructivism does not have a monopoly on these insights. They can be found in the work of thinkers as diverse as Mach, Duhem, Bachelard, Popper, and Polanyi.

CONSTRUCTIVIST TEACHING OF THE CONTENT OF SCIENCE

One response to criticism of constructivist theory is to say that constructivist pedagogy is valuable and should be encouraged, even if the theory is debatable. This position is understandable, but it rests on a moot point: How efficacious is constructivist pedagogy in teaching science?

One prominent constructivist, Richard White, has said 'although the research on alternative conceptions has sparked interest in content, it has not yielded clear advice about how to teach different topics (Fensham, Gunstone & White, 1994, p. 255). Given the necessity for any science programme to teach the content of science this is a serious failure.

The difficulty for constructivism posed by teaching the content of science is not just a practical one, it is a difficulty that exposes a fundamental *theoretical* problem for constructivism – if knowledge cannot be imparted, and if knowledge must be a matter of personal construction, then how can children come to knowledge of complex conceptual schemes that have taken the best minds hundreds of years to build up?

Many science educators are interested in finding out how, on constructivist principles, one teaches a body of scientific knowledge that is in large part abstract (depending on notions such as velocity, acceleration, force, gene), removed from experience (propositions about atomic structure, cellular processes, astronomic events), has no connection with prior conceptions (ideas of viruses, antibodies, molten core, evolution, electromagnetic radiation), and is alien to common-sense, and in conflict with everyday experience, expectations and concepts? Teaching a body of knowledge involves not just teaching the concepts, but also the method, and something of the methodology or theory of method. How all of this is to be taught, without teachers actually conveying something to pupils, is a moot point.

Joan Solomon, a prominent British science educator, well articulates the problem:

> Constructivism has always skirted round the actual learning of an established body of knowledge . . . students will find that words are used in new and standardised ways: problems which were never even seen as being problems, are solved in a sense which needs to be learned and rehearsed. For a time all pupils may feel that they are on foreign land and no amount of recollection of their own remembered territory with shut eyes will help them to acclimatise. (Solomon, 1994, p. 16)

The constructivist research of Rosalind Driver and scholars at Leeds University illustrates the 'skirting around' to which Solomon draws attention. In a recent book the Leeds group reasonably enough maintain that:

> . . . learning science involves being initiated into the culture of science. If learners are to be given access to the knowledge systems of science, the process of knowledge construction must go beyond personal empirical enquiry. Learners need to be given access not only to physical experiences but also to the concepts and models of conventional science. (Driver et al., 1994b, p. 6)

There is near unanimity on this claim – conservatives and progressivists all agree, with perhaps just discovery-learners dissenting. The claim echoes the Leeds group's oft-repeated assertion that constructivism is different from discovery learning (on this, see Miller & Driver 1987). But having made the above claim, the Leeds group go on to say that:

> The challenge for teachers lies in helping learners to construct these models for themselves, to appreciate their domains of applicability and, within such domains, to use them.

One might reasonably ask whether, at this point, learning theory, or ideology, is simply getting in the way of good teaching. Why must learners construct for themselves the ideas of potential energy, mutation, linear inertia, photosynthesis, valency, and so on? Why not explain these ideas to students, and do it in such a way that they understand them? Certainly a challenge for constructivist teachers lies in helping learners construct these ideas without violating constructivist learning principles. The Leeds group recognise this, and go on to say:

> If teaching is to lead pupils towards conventional science ideas, then the teacher's intervention is essential, both through providing appropriate experiential evidence and making the theoretical ideas and conventions available to pupils. (Driver et al. 1994b, p. 6)

This is perhaps the precise point where Joan Solomon's 'skirting around' is evidenced. How can a teacher make 'the theoretical ideas and conventions available to pupils' without explaining them, without illustrating them, without showing their interconnections. In brief, without teaching them to pupils?

Constructivists addressed the problem of teaching the content of science at an international seminar held at Monash University in 1992. Its published proceedings were titled *The Content of Science: A Constructivist Approach to its Teaching and Learning* (Fensham, Gunstone & White, 1994). Rosalind Driver and colleagues made a contribution to the seminar on 'Planning and Teaching a Chemistry Topic from a Constructivist Perspective'. They had children put nails in different places and observe the rate at which they rusted. They remarked that:

> The theory that rusting is a chemical reaction between iron, oxygen and water, resulting in the formation of a new substance, is not one that students are likely to generate for themselves. (Fensham, Gunstone & White 1994, p. 206)

Indeed. After ten pages describing how the teacher tries to 'keep faith with students reasoning . . . yet lead them to the intended learning goals' (p. 207), we are told that 'The process of investigating personal ideas and theories may lead students to reflect upon and question them. At the same time, it is unlikely to lead to the scientific view' (p. 218).

Quite so. But where does this leave constructivism as a putatively useful theory for science teachers?

Most science teachers realise this difficulty. They try their best to explain things clearly, to make use of metaphors, to use demonstrations and practical work to flesh out abstractions, to utilise projects and discussions for involving students in the subject matter, and so on. They realise that many, if not most, things in science are beyond the experience of students and the capabilities of school laboratories to demonstrate. The cellular, molecular and atomic realms are out of reach of school laboratories, as is most of the astronomical realm. Most of the time even things that are

within reach do not work. It is a rare school experiment that is successful. For children, a great deal of science has to be taken on faith. Good teachers do their best, and try to point out why faith in science is warranted.

Some would say that the constructivist/anti-constructivist argument reduces to a mere verbal preference: constructivist teachers (of the Leeds variety) perhaps do make the concepts available in the sense of teaching them, but they prefer to talk of student construction, while traditionalists prefer to talk of transmission. Where there is a failure of match between the pupil's idea and the scientific idea, constructivists prefer to talk of imperfect construction, and traditionalists prefer to talk of failure of attention, imperfect comprehension, inadequate preparation. Provided both groups of teachers are doing the same thing, and judging the outcome by the degree to which the pupil understands the current scientific concept, then the argument could be seen as merely a verbal one over the name of a label.

But it is not just a verbal matter. A practical, but not insignificant, consideration is that science teachers are overwhelmed by challenges – pupils' lack of interest in science, teachers' inadequate knowledge of science, schools' lack of resources, society's lack of interest in education – they do not need to be further weighed down by illusory challenges, if indeed this is what the constructivist challenge amounts to. A theoretical consideration is the very justification of science in the curriculum. If Western science is truly just one among many equally warranted ways of making sense of experience, and it truly does not tell us anything about the world in which we live, then traditional arguments for compulsory school science, and 'Science for All', need to be re-thought.

CONCLUSION

The foregoing considerations serve to highlight the importance, for both constructivists and their critics, of getting clear about just what are, and are not, the epistemological commitments of constructivism. And what relationship these commitments have, if any, to classroom practice. Given the influence of constructivism on education reform, teacher education and pedagogy, these are not idle investigations.

It is hoped that this issue of *Science & Education* will advance these investigations.